

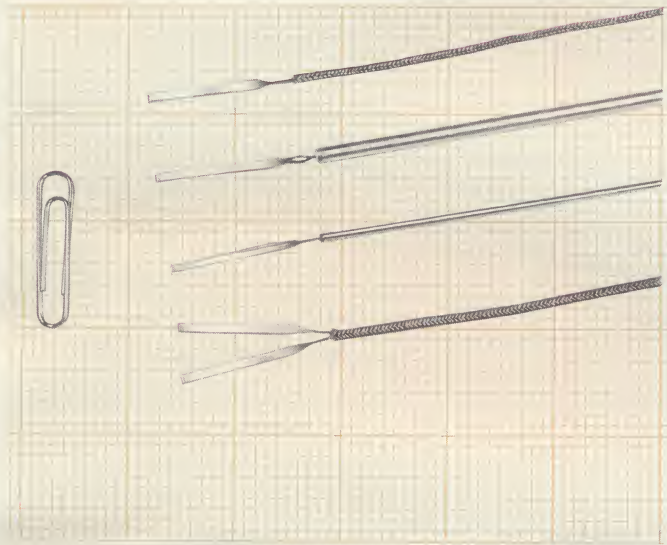
# NANMAC

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## FLEXIBLE RIBBON AND INTRINSIC THERMOCOUPLES

NO. TB-167



### Flexible Ribbon Thermocouples

Many research and industrial applications require the use of an economical thermocouple with fast response characteristics. This can be done with round wire thermocouples made out of very small diameter wires. However, small diameter wires cause many difficulties, among which are fragile junctions, high lead resistances, difficult attachments, poor thermal contacts etc.

Rolling the round wires in the vicinity of the thermal junction into thin ribbons eliminates these problems and also yields several additional advantages such as: the thermal junction is more reliable in that several weld joints are now possible, the lead resistance is low since larger wires can be used, fragility is also reduced because of the larger leads, the ribbons are very flexible and will bend to mate with irregular surfaces, attachment problems are simpler since the ribbons can be easily spot welded, brazed, soldered, glued, potted or clamped to the test wall, excellent thermal contact is made with the test wall and response times of 20 milliseconds in hot water immersion tests or 50 milliseconds in moving air tests can be obtained with the Ribbon Thermocouples.

**NANMAC** offers these Ribbon Thermocouples in two basic styles, i.e., one style has fiberglass insulation on the lead wires and it is usable to about 700° F maximum operating temperatures. The other style has ceramic insulation on

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the lead wires and a stainless steel sheath. Both styles are available in a wide range of wire sizes and types of elements. Figures 1 and 2 show the essential features of these two styles of Ribbon Thermocouples.

### Intrinsic Thermocouple

In certain applications it is desired to weld the ribbon elements individually to the metallic wall of the test item. Because of the Law of Intermediate Metals as applied to thermocouples, this can be done without introducing any errors in the system. This arrangement is commonly referred to as the "Intrinsic Thermocouple." Additional technical details and characteristics of the Intrinsic Thermocouple may be found in the attached article by G. R. Dittbenner of the University of California, Lawrence Radiation Lab. Fig. 3 shows the essential features of the Intrinsic Thermocouple.

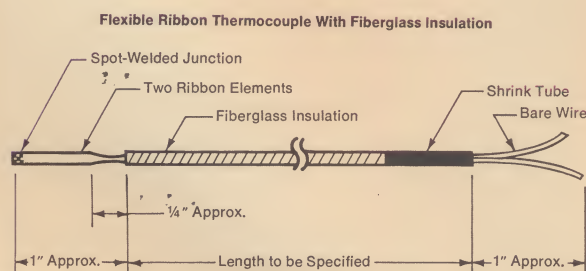
**NANMAC** offers Intrinsic Thermocouples with the same specifications as our Flexible Ribbon Thermocouples. The length of the ribbon elements in the NANMAC Intrinsic Thermocouple is about  $\frac{3}{4}$  inch. This length can be reduced if necessary at the time of installation. When ordering Intrinsic Thermocouples simply add the suffix (IT) to the Catalog Number of our Flexible Ribbon Thermocouples.

## Prices and Specifications of Flexible Ribbon Thermocouples

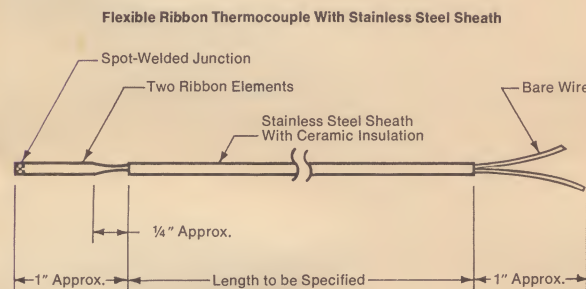
Cat. No.	Wire Dia. (Inches)	Ribbon Thickness (Approx.)	Insulation	S. S. Sheath Dia.	Unit Price*	Additional Per Foot
36FF	.005	.001"	fiberglass	—	\$5.00	\$0.20
30FF	.010	.0015"	fiberglass	—	\$5.00	\$0.20
24FF	.020	.0025"	fiberglass	—	\$5.00	\$0.20
40SS	.006	.001"	ceramic	.040"	\$8.00	\$2.25
62SS	.013	.0015"	ceramic	.062"	\$7.50	\$2.00
125SS	.020	.0025"	ceramic	.125"	\$7.50	\$2.75

\*Unit prices apply for standard lengths of 12 inches. (Prices subject to change without notice.)

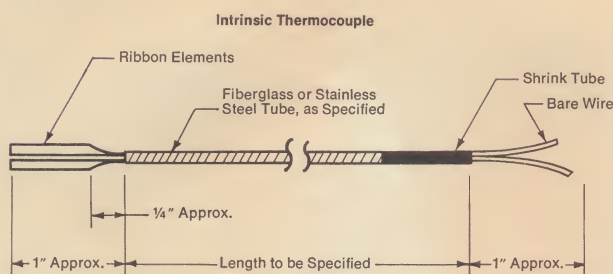
**Figure 1**



**Figure 2**



**Figure 3**



Above prices apply for the following types of thermocouples:

Thermal Elements	ISA Type	Temperature Range
copper/constantan	T	-312° to 750°F
chromel/constantan	E	-320° to 1830°F
iron/constantan	J	-320° to 1401°F
chromel/alumel*	K	-310° to 2505°F

\*TM of Hoskins Mfg. Co.

When ordering, specify Catalog Number, ISA Type and Length.

**Example:** NANMAC Flexible Ribbon Thermocouple  
Cat. No. 36FF, ISA-Type J, length 12 feet.

When ordering Intrinsic Thermocouples simply add the suffix (IT) to the Catalog Number of our Flexible Ribbon Thermocouples.

**Example:** NANMAC Intrinsic Thermocouple  
Cat. No. 36FF(IT), ISA-Type J, length 12 feet.

Prices of the Intrinsic Thermocouples is \$0.50 per unit cheaper than equivalent prices of the Flexible Ribbon Thermocouples.

### Quantity Discounts:

1-20, None

21-50, less 5%

51-100, less 10%

101-500, less 15%

501 and over,  
upon request

**Delivery:** Stock to two weeks

**FOB:** Needham Heights,  
Massachusetts

**Terms:** Net 30 days

**Minimum Billing:** \$20.00

For other types of insulation, sheath materials, wire sizes, thermocouple alloys, etc., please send details to our main office for a prompt proposal.

NEWSLETTER

No. 64-5

September 17, 1964

Flexible Ribbon Thermocouples

Many industrial applications require the use of an economical thermocouple with fast response characteristics. In order to achieve response characteristics in the millisecond range using round wire thermocouple elements, you must use wire sizes of 0.005" diameter and smaller. This causes some undesirable problems such as:

- (a) Fragile thermal junction which is easily broken during operation or installation.
- (b) Difficult attachment problems.
- (c) High internal resistance and lead wire resistance which may eliminate the use of economically priced pyrometers.
- (d) The use of adaptors so that the extension leads can be larger in diameter for handling and resistance purposes.
- (e) High cost and long delivery times.

Other problems associated with fine wire thermocouples can be listed, but the above suffice to illustrate the need for a better thermocouple design. Using our ribbon principle we have designed a simple, economical thermocouple to yield the response time equivalent to a 0.002" diameter round-wire thermocouple with none of the disadvantages listed above. Here's how it's done:

The thermocouple leads are stripped of insulation at the thermal junction end and the round wires are rolled into ribbons of thickness of about 0.002 inches for a length of about 3/4". The round wire can be gage #24, 26, or 30 with diameters of 0.020", 0.016", or 0.010" respectively. The ribbons are then electrically spot welded together several times to form a lap-welded thermal junction in an area of about 1/10" square at the end of the exposed 3/4" long ribbons. This design has the following advantages:

- (a) Thermal junction consists of several weld joints rather than just one, thereby improving reliability of the weld joint.
- (b) Response time is about 20 milliseconds in hot water immersion tests and 50 milliseconds in moving air tests.
- (c) The internal resistance of the junction and the lead wires is the same as the large diameter leads ie, #24, #26, or #30 which were used to fabricate the thermocouple.
- (d) The exposed ribbon elements which are about 3/4" long are the ideal shape for subsequent attachment to your test item. This thermal junction can be easily spot welded, brazed, soldered, glued, potted, clamped, etc to your test wall. In fact it can be clamped between two washers or under a bolt if desired.
- (e) The ribbons are very flexible and if necessary can be bent to any desired shape.
- (f) The flexible lap-welded ribbon junction is much more resistant to mechanical shocks vibration and thermal shocks than beaded junctions.

FIGURE - 1

FLEXIBLE RIBBON THERMOCOUPLE WITH  
FIBERGLASS INSULATION

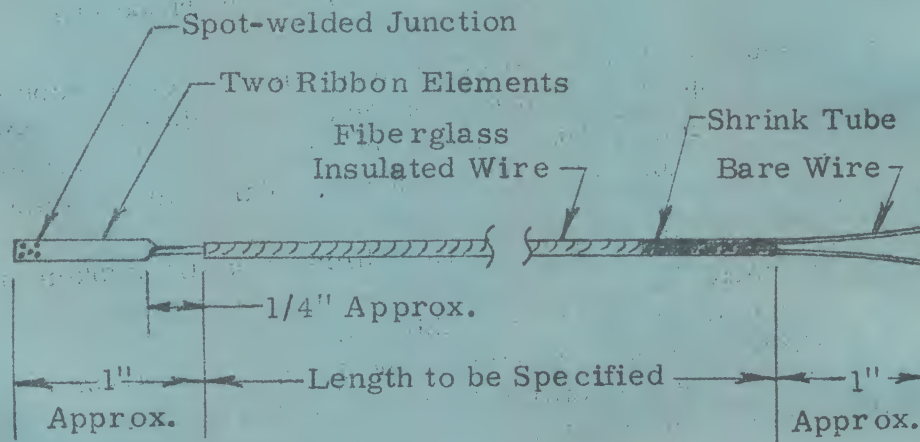


FIGURE - 2

FLEXIBLE RIBBON THERMOCOUPLE WITH  
STAINLESS STEEL SHEATH

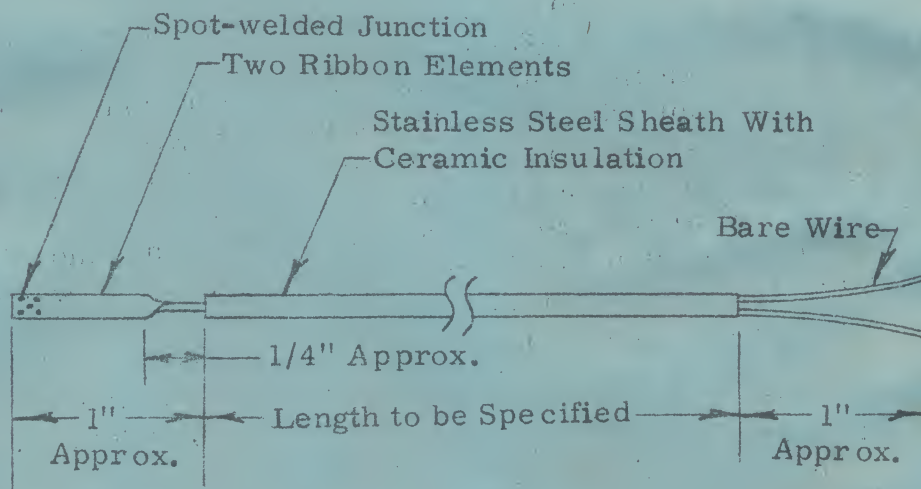




FIG. 1. FAST-RESPONSE THERMOCOUPLE

# Intrinsic Thermocouple for Fast Response

GERALD R. DITTBENNER

University of California, Lawrence Radiation Lab.

**A** NEED HAS DEVELOPED for a transducer capable of measuring very fast temperature transients on materials heated by a neutron radiation pulse. At Lawrence Radiation Laboratory special commercial units of Baldwin-Lima-Hamilton type TCRC-ES-50 with exposed 0.001" diameter wires were tested, and feasibility for fast response established. However, this design was not easily adaptable to field use, and a new design was developed for which stock thermocouple wire of small sizes was used.

The new units were made of 0.001" and 0.0005" wire, flattened to a ribbon 200- $\mu$ in thick. The two wires of each thermocouple are individually welded to the test specimen about  $\frac{1}{32}$ " apart so that the specimen completes the circuit and forms an intrinsic thermocouple installation.

Chromel-constantan Type E thermocouple wire was selected because of its high output (34  $\mu$ V/ $^{\circ}$ F) and its compatibility with the required temperature range. Each thermocouple wire was individually spot-welded to the test surface, thus completing the electrical circuit and forming an intrinsic junction (Fig. 1). Flattened ribbon was preferred over round wire since it was easier to see during fabrication and installation, and its use made it possible to avoid the reduced cross-sectional area and stress concentration which can occur in welding.

The Kukla fast-burst reactor at Livermore was used to establish response times of various diameter thermocouple wires. The "intrinsic" technique was used on uranium samples. The Kukla energy pulse is 200  $\mu$ sec wide with a half-energy pulse width of about 60  $\mu$ sec (Ref. 1).

The typical response of the various thermocouple sizes to this quasi-step temperature rise is shown

(Fig. 2). The temperature of the test sample reached a maximum in less than 1 msec and thermocouple data were measured from 1 msec to 60 msec after the start of heating.

The response of the 0.001" thermocouple was adequate for most applications, and it has been used extensively for the fast-response measurements. Recently, however, a 0.0005" flattened intrinsic thermocouple gives even faster response; indicating approximately 100% of full-scale value of the quasi-step temperature input after approximately 1 msec. In traditional thermometry the RC time constant, or time required to indicate 63.2% of the temperature rise, is frequently used.

A thermocouple responding like an idealized RC time-constant system will indicate 99.3% of its full-scale temperature after 5 time constants. The intrinsic thermocouple, however, requires approximately 50 time constants to indicate 99% of peak temperature because: (1) The temperature input is not a pure instantaneous step rise; (2) The thermocouple leads draw heat away from the junction for a time before reaching equilibrium. The 63.2% time constant, therefore, is a very poor measure of the response compared to the nominal 100% response time. However, out of respect for tradition and for completeness, the time constant for the 0.0005" intrinsic thermocouple has been conservatively estimated to be 20  $\mu$ sec.

Apart from the above qualities the 0.0005" unit provides valid temperature measurements to about 5% accuracy (agreeing with the monitor thermocouple following the pulse of the Kukla-burst reactor) and no calibration changes were observed, even after several reactor exposures. It has successfully measured temperatures to 1300 $^{\circ}$ F, is small, has been impact-tested to 5000 g, and is easily fabricated and installed.

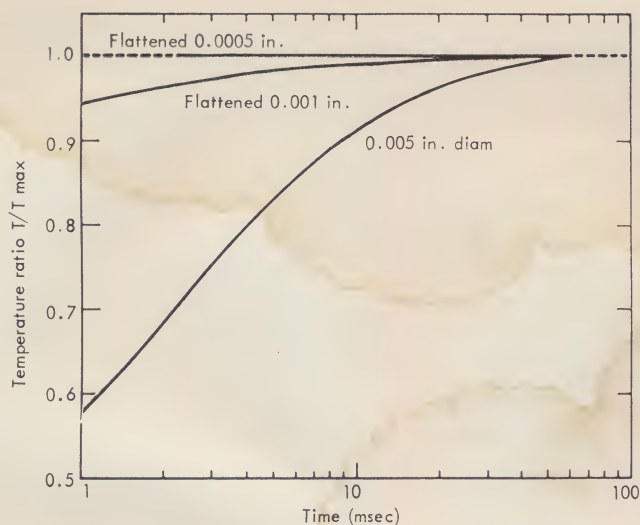


FIG. 2. TYPICAL RESPONSE curves of various TC wires

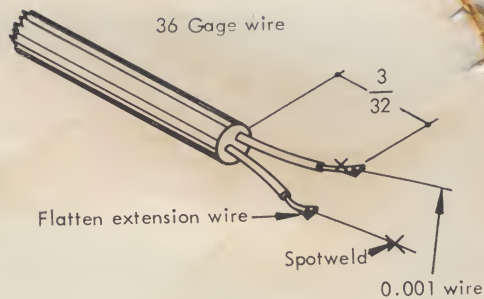


FIG. 3. STRIPPING BACK lead wire

FIG. 4. METHOD of checking polarity

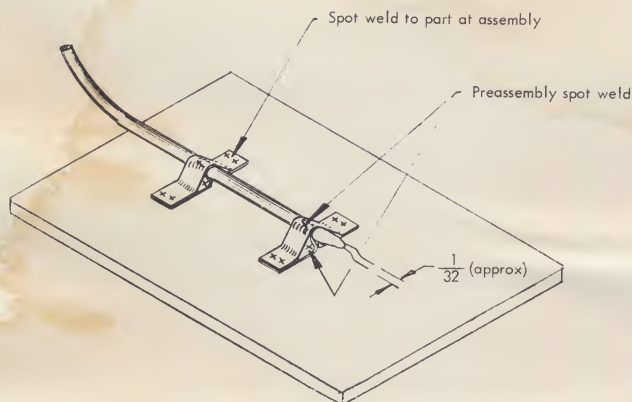


FIG. 5. NICHROME STRAPS attached to cable jacket

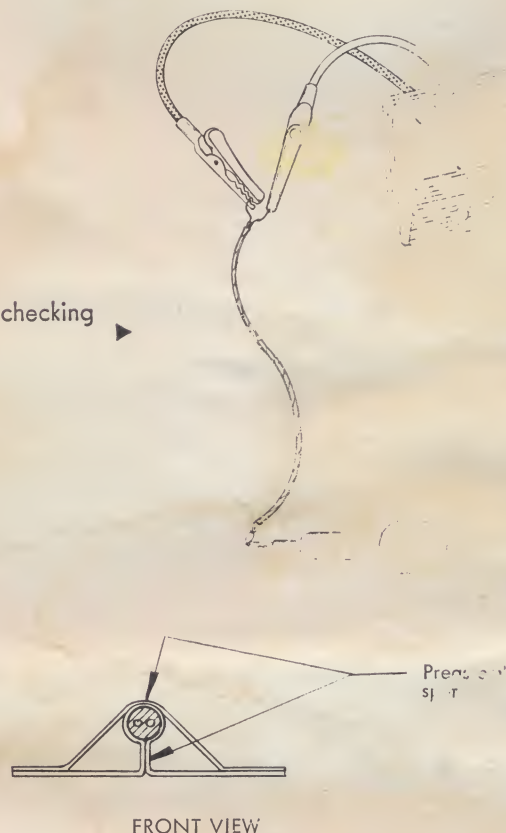


FIG. 6. THERMOCOUPLE assembly to specimen

### Fabrication Details

**Equipment.** (1) Model 1101 Unitek miniature welding head, (2) Model 1049B Unitek dual-range power supply, (3) American Optical Co. microscope.

**Materials.** (1) Hysol Epoxi-Patch kit #1C, (2) 0.003" x 0.125" Nichrome strap, (3) Omega Engineering Inc. precision thermocouple wire, Chromel-Constantan 0.001" and 0.0005" dia., (4) Raychem type 10155, 30 gage (0.01") Chromel-Constantan lead wire shielded with Hyrad jacket.

**Procedure.** (1) Select cable lead wire and strip back, Fig. 3, (2) Polarity- check cable lead, Fig. 4, (3) Construct Nichrome straps and attach to cable jacket, Fig. 5, (4) Flatten fine thermocouple wire between two precision surface plates using press Fig. 3, (5) Flatten ends of cable leads with smooth jaw pliers and spot-weld fine thermocouple wire to cable leads, Fig. 3, (6) Polarity-check the completed circuit, Fig. 4,

(7) Pot with Hysol cement and cure according to factory instructions, (8) Spot-weld Nichrome thermocouple assembly to test specimen, (9) Rigid installation, Fig. 6, (10) Spot-weld to flattened thermocouple ribbon, specimens about 0.0313" apart (intrinsic fluctuation) with a flexible strain-relief loop in each lead.

### Acknowledgment

The author wishes to thank Ray Freynik of the Weapons Test Group for his assistance in preparing this manuscript.

### Reference

1. Ramus, Joseph E., Radiation Effects in Strain Gage and Temperature Circuits in a Pulsed Reactor Environment, Report UCRL-7755, University of California, Livermore Laboratory, March 1964.